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Mitigating Highway Visibility Problems

Prepared for
National Highway Visibility Conference
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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research. Internet hyperlinks in TSRs are active at the time of publication, but changes on the host server can make them obsolete.

Background

Highway visibility distance is reduced by fog and heavy precipitation, as well as wind-blown snow, dust and smoke. Low visibility conditions cause increased speed variance, which increases crash risk. In the United States in 2001, nearly 44,000 vehicle crashes occurred in fog: more than 670 people were killed and more than 19,000 injured in these crashes.[1]

[1]Low Visibility – FHWA Road Weather Management Program (2004)
http://www.ops.fhwa.dot.gov/weather/weather_events/low_visibility.htm.

In Wisconsin, 595 crashes occurred in fog, smog and smoke weather conditions in 2002, resulting in 22 persons killed and 372 injured.[2] Fog-related crashes occur virtually statewide in Wisconsin, wherever conditions are right for fog formation, such as low-lying areas near marshes and lakes.[3]

[2]2002 Wisconsin Traffic Crash Facts
http://www.dot.state.wi.us/safety/motorist/crashfacts/docs/crashfacts.pdf: scroll to Page 36- Weather Conditions.

[3]*Driving in fog requires extra caution, slower speeds* – Wisconsin Department of Transportation News (Oct. 11, 2002)
http://www.dot.wisconsin.gov/news/news/2002general/opa-drivinginfog399.htm.

WisDOT, FHWA, AAA Wisconsin and other organizations are co-sponsoring the premier National Highway Visibility Conference May 18 to 19, 2004 at the University of Wisconsin-Madison. Conference objectives include advancing the state of the practice related to roadway visibility detection and mitigation measures, with an emphasis on fog. The primary goal is to establish a framework for advancing visibility-oriented technology, state/federal programs and an on-going national dialogue.[5]

[5]NHVC 2004
http://www.topslab.wisc.edu/nhvc/index.htm.

WisDOT's RD&T Program was asked to prepare a Transportation Synthesis Report for distribution to conference attendees that would provide an overview of best practices and emerging technology for mitigating highway visibility problems.

Summary

FHWA's Road Weather Management Program has developed effective tools to observe, predict and alleviate the impacts of weather on roads. The program Web site provides a comprehensive look at weather responsive transportation management in the U.S. that includes innovative FHWA activities (see **FHWA**) and creative state DOT projects that are successfully mitigating low visibility problems (see **State DOTs**). Highlights include:

* The Road Weather Management Program is working with transportation and weather partners to develop siting guidelines for environmental sensor stations in the roadway environment in order to enhance observation capabilities and define requirements for road weather observing systems.

* Utah DOT employs two strategies to mitigate fog problems. A low visibility warning system notifies motorists of safe travel speeds and promotes more uniform traffic flow along a segment of I-215 in Salt Lake City. In northern Utah's mountain valleys, maintenance personnel use liquid carbon dioxide to disperse "cold" fog (less than 32 degrees F) and improve visibility along sections of Interstates, U.S. Highways and secondary roads.

Other Agencies are also examining fog dispersal strategies. The U.S. Air Force, addressing the topic in *Air Force 2025 Final Report*, discusses hygroscopic seeding as an effective technique for dissipating "warm" fog (more than 32 degrees F). This technique uses agents that absorb water vapor and "can be accomplished from the ground." Overseas, the Italian government has reported successful testing of technology that dispenses liquefied nitrogen to dissipate warm fog and cold fog.

Regarding seeding techniques, the Air Force has reported that smart materials based on nanotechnology are currently being developed with gigaops computer capability at their core that could adjust their size to optimal dimensions for a given fog seeding situation and make adjustments throughout the process (See **Emerging Technology**). The agency reports further that field experiments with lasers have demonstrated a capability for dissipating warm fog. The Air Force is also evaluating a prototype laser "flashlight" with a beam that can penetrate smoke and fog at more than twice the distance of white light. A proposal from Veridian Engineering Inc. to the Petroleum Technology Alliance Canada for mitigating low visibility problems discusses strategies including infrared sensor technologies, "which can be very effective in 'seeing' through thick fog, heavy rain, snow and smoke." The High Speed Integrated Circuits group at the California Institute of Technology has implemented a novel antenna array system on a single, silicon chip. The new technology helps pave the way for built-in radar systems for cars that will enable drivers to "see" the roadscape clearly on foggy nights via an image screen in front of them.

FHWA – Road Weather Management Program

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#projects.
This section highlights some of the projects and activities within the FHWA Road Weather Management Program including:

- Environmental Sensor Station (ESS) Siting Guidelines Project

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#1
In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program is working with transportation and weather partners to develop siting guidelines for ESS in the roadway environment. The ESS Siting Guidelines project will produce consistent guidance for state and local agency personnel responsible for procuring, siting, operating and maintaining ESS along the nation's roads. (For a FHWA overview of ESS technologies, see: http://www.ops.fhwa.dot.gov/weather/best_practices/EnvironmentalSensors.pdf.)

- Surface Transportation Weather Decision Support Requirements (STWDSR) Project

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#2
In 1999, decision support requirements of 44 types of transportation managers were studied in the STWDSR project. The STWDSR Version 1.0 report documents the weather information requirements of all road users and operators. In 2000, weather threat scenarios were used to identify specific decisions made in winter road maintenance, the timing of decisions, and the expected confidence of the decisions at various time horizons. The STWDSR Version 2.0 reports focus on the specific decision support requirements of winter maintenance managers. Version 2.0 also presents an operational concept for a decision support system. Specifically, the STWDSR effort served as the basis for the Maintenance Decision Support System (MDSS). STWDSR reports contain more information on the project: http://www.ops.fhwa.dot.gov/weather/best_practices/1024x768/transform_param2.asp?xslname=pub.xsl&xmlname=publications.xml&keyname=164.

- Maintenance Decision Support System (MDSS) Project

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#3
The MDSS project is a multiyear effort to prototype and field test advanced decision support for winter maintenance managers. Prototype development began in September 2000 with formation of a stakeholder group and definition of winter road maintenance requirements under the STWDSR project. With these requirements, a consortium of national laboratories developed a prototype for an operational system in 2001. The first MDSS functional prototype was demonstrated and tested in Iowa from February to April 2003. A second demonstration took place during winter 2003-2004. As the labs release prototype software modules, private vendors and others will incorporate them into their product lines and develop applications tailored to the needs of state DOTs. Such customized decision support systems will ultimately increase the productivity of road maintenance agencies and result in safer roads during the winter. Further details on the MDSS prototype and demonstration can be found in The Winter Maintenance Decision Support System (MDSS): Demonstration Results and Future Plans:
http://www.ops.fhwa.dot.gov/weather/best_practices/MDSSpaperAMS2004.pdf.

- Weather Responsive Traffic Management

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#4
In January 2003, the Road Weather Management Program released the Weather-Responsive Traffic Management Concept of Operations (http://www.ops.fhwa.dot.gov/weather/best_practices/WeatherConOps0103.pdf) highlighting the weather-related needs of managers responsible for freeway and arterial route operations. This draft concept of operations addresses road weather data collection, assessment of weather impacts on roadway networks, operational strategies to control traffic during adverse weather, as well as research needs. It serves as the basis for future work to develop, test and evaluate these mitigation strategies. The need for a systematic approach to the significant challenge of managing traffic during inclement weather is discussed in Research Needs for Weather-Responsive Traffic Management (http://www.ops.fhwa.dot.gov/weather/best_practices/WxRspTfcMgmtTRB2004.pdf).

- Best Practices for Road Weather Management

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#5
Maintenance, traffic and emergency managers across the country were interviewed to capture successful and innovative strategies used to mitigate the impacts of fog, high winds, snow, rain, ice, flooding, tornadoes, hurricanes and avalanches. The Best Practices for Road Weather Management resource contains 30 case studies of systems in 21 states that improve roadway safety, mobility and/or productivity. Each case study has six sections including a general description of the system, system components, operational procedures, resulting transportation outcomes, implementation issues, as well as contact information and references. This resource also contains an overview of environmental sensor technologies, an acronym list, more than 200 road weather publications, and online resources (including 39 statewide road weather condition Web sites). The Best Practices for Road Weather Management, Version 2.0 CD-ROM was released in May 2003 and can be requested by visiting http://www.nawgits.com/fhwa/rw_mgt_cd_req.html. To share information on road weather management strategies in your state, contact Lynette Goodwin at lynette.goodwin@mitretek.org.

- Fundamentals of Road Weather Management Training Course

http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#6
FHWA tentatively planned to offer a training course on the Fundamentals of Road Weather Management in spring 2004. The one-day course is designed for traffic, emergency and maintenance managers, as well as safety engineers and anyone involved in highway operations or maintenance. The objectives of the course are to provide background on the fundamentals of meteorology as they pertain to Road Weather Information Systems (RWIS), to provide participants with the skills to recognize crosscutting weather impacts on roadway operations, to explain the range of effective and open RWIS solutions for various management practices, and to identify the technical and institutional challenges of implementing RWIS. Additional course details were to be listed on the National Highway Institute Web site (http://www.nhi.fhwa.dot.gov/default.asp) when course content and schedules have been finalized.

State DOTs – Low Visibility Mitigation

FHWA Road Weather Management Program
http://www.ops.fhwa.dot.gov/weather/weather_events/low_visibility.htm

- Alabama DOT Low Visibility Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/001.pdf
In March 1995 a fog-related crash involving 193 vehicles occurred on the seven-mile Bay Bridge on Interstate 10. The crash prompted the Alabama DOT to deploy a low visibility warning system. The system was integrated with a tunnel management system near Mobile. Although labor-intensive, the system has improved safety by reducing average speed and minimizing crash risk in low visibility conditions.

- California DOT Motorist Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/002.pdf
Visibility on freeways in the Stockton-Manteca area of San Joaquin County is reduced by wind-blown dust in summer and dense, localized fog in winter. In the past low visibility contributed to numerous chain-reaction collisions in the San Joaquin Valley. To improve roadway safety on southbound Interstate 5 and westbound State Route 120, Caltrans implemented an automated system to warn motorists of driving hazards. The motorist warning system improved highway safety by significantly reducing the frequency of low-visibility crashes. Nineteen fog-related crashes occurred in the four-year period before the system was deployed. Since the system was activated in November 1996 there have been no fog-related crashes. Vehicle guidance operations by the Department of Emergency Management are also utilized to minimize crash risk.

- Idaho DOT Motorist Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/008.pdf
The Idaho DOT installed a motorist warning system on an 100-mile section of Interstate 84 in southeast Idaho and northwest Utah. This road segment was highly prone to multivehicle crashes when *blowing snow or dust reduced visibility. From 1988 to 1993, poor visibility contributed to 18 major crashes involving 91 vehicles, 46 injuries and nine fatalities. Traffic managers display advisory messages to motorists to influence driver behavior under adverse conditions. Advisory information presented by traffic managers prompted changes in driver behavior, improving safety and mobility.

*The following reports by Ronald D. Tabler (Tabler & Associates) are also excellent resources for addressing the problem of blowing snow:
-- *Design Guidelines for the Control of Blowing and Drifting Snow*, available online at http://gulliver.trb.org/publications/shrp/SHRP-H-381.pdf; and
-- *Snow Fence Guide*, available online at http://gulliver.trb.org/publications/shrp/SHRP-H-320.pdf.

- New Jersey Turnpike Authority Speed Management

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/016.pdf
The New Jersey Turnpike Authority operates an Advanced Traffic Management System to control 148 miles of the turnpike, which is one of the nation's most heavily traveled freeways. Various subsystems are employed to monitor road and weather conditions, manage traffic speeds and notify motorists of hazardous conditions. Speed management and traveler information techniques have improved roadway safety in the presence of fog, snow and ice.

- South Carolina DOT Low Visibility Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/021.pdf
As a result of a federal court decision the South Carolina DOT was required to incorporate fog mitigation technologies during construction of the Interstate 526 Cooper River Bridge. SCDOT deployed a low visibility warning system on seven miles of the freeway to inform drivers of dense fog conditions, reduce traffic speeds and guide vehicles safely through the fog-prone area. The low visibility warning system enhances mobility by providing traveler information and clearly delineating travel lanes with pavement lights. No fog-related crashes have occurred since the system was deployed.

- Tennessee Low Visibility Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/022.pdf
On Dec. 11, 1990 visibility on a segment of Interstate 75 in southeastern Tennessee was less than 10 feet. In both northbound and southbound lanes extremely low visibility contributed to chain-reaction collisions involving 99 vehicles, 42 injuries and 12 fatalities. The crash prompted the design and implementation of a low visibility warning system on the interstate freeway. The system covers 19 miles including a three-mile fog-prone section above the Hiwassee River and eight-mile road sections on each side of the river. There have been more than 200 crashes, 130 injuries and 18 fatalities on this highway section since the interstate opened in 1973. Safety improved significantly after deployment of the warning system in 1994, as only one crash has occurred in fog.

- Utah DOT Fog Dispersal Operations

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/025.pdf
In northern Utah widespread, “cold” fog (less than 32 degrees F) can persist in mountain valleys for weeks. Utah DOT maintenance personnel use liquid carbon dioxide to disperse fog and improve visibility along segments of Interstates 15, 70, 80 and 84; U.S. Highways 40, 89 and 91; and secondary roads in Cache Valley and Bear Lake Valley. The treatment strategy includes the application of anti-icing chemicals as fog is dispersed to prevent moisture from freezing on the pavement. The fog dispersal treatment strategy improves roadway mobility and safety. This strategy can increase visibility distance behind the maintenance vehicle from 33 feet to 1,640 feet in less than 30 minutes. The treatment remains effective for 30 minutes to four hours, depending on air temperature and wind speed. Improved visibility has significantly reduced rear-end crashes into maintenance vehicles, enhancing the safety of DOT personnel and the public.

- Utah DOT Low Visibility Warning System

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/026.pdf
Due to high traffic volumes and local conditions conducive to dense fog formation, Utah DOT deployed a low visibility warning system on Interstate 215 to notify motorists of safe travel speeds and to promote more uniform traffic flow. The warning system was installed on a low-lying, two-mile highway segment above the Jordan River in Salt Lake City where several multivehicle, fog-related crashes have occurred. An evaluation of the warning system indicated that overly cautious drivers sped up when advisory information was displayed, resulting in a 15 percent increase in average speed from 54 to 62 mph. This increase caused a 22 percent decrease in speed variance from 9.5 to 7.4 mph. Reducing speed variance enhanced mobility and safety by promoting more uniform traffic flow and minimizing the risk of initial, secondary and multivehicle crashes.

- Washington State DOT Speed Management

http://www.ops.fhwa.dot.gov/weather/best_practices/CaseStudies/029.pdf
Interstate 90, which is the primary east-west route across Washington State, experiences rain and fog in summer months and snow and ice in winter. This freeway crosses the Cascade Mountains through Snoqualmie Pass, a popular tourist destination. Roadway geometry, the volume of truck traffic (22 percent), and recreational travelers unfamiliar with local conditions contributed to a winter crash rate that was four times the annual average. WSDOT employs a speed management technique on a 40-mile segment of the freeway to improve roadway safety in the presence of fog, snow and ice. Speed management has improved roadway safety by prompting drivers to significantly decrease speed in inclement conditions. A University of Washington study found that although speed variance increased slightly, speed management reduced average speed by up to 13 percent.

Other Agencies – Low Visibility Mitigation

United States Air Force - Weather Control
From: Air Force 2025 Final Report (http://www.au.af.mil/au/2025/), Vol 3, Weather as a Force Multiplier
U.S. Air Force, Air University at Maxwell AFB, AL (August 1996)
http://www.geocities.com/Area51/Shadowlands/6583/project335.html.
Scroll to Fog:
Decades of research show that fog dissipation is an effective application of weather-modification technology with demonstrated savings of huge proportions for both military and civil aviation. Local municipalities have also shown an interest in applying these techniques to improve the safety of high-speed highways transiting areas of frequently occurring dense fog.

Warm fog occurs at temperatures above 32 degrees F and accounts for 90 percent of the fog-related problems encountered by flight operations. The best-known dissipation technique is heating because a small temperature increase is usually sufficient to evaporate the fog. Since heating usually isn't practical, the next most effective technique is hygroscopic seeding. Hygroscopic seeding uses agents that absorb water vapor. This technique is most effective when accomplished from the air but can also be accomplished from the ground. Optimal results require advance information on fog depth, liquid water content and wind.

WMO's Activities on Weather Modification – Cooperation with Italy
Statement at the Italian Senate Hearing on Weather Modification, 1999
http://www.wmo.ch/files/sg_statements/english/SG102E.pdf.
(The World Meteorological Organization (WMO) is a Geneva-based intergovernmental organization and a specialized agency of the United Nations. In 1975, the Seventh World Meteorological Congress, the supreme body of WMO, established a formal Weather Modification Program. Precipitation enhancement, hail suppression and fog dissipation were targeted to be among the most significant activities of the program.)

Page 3- For fog dissipation, certain techniques have been shown to be effective in clearing warm fog through heating-evaporation or seeding with hygroscopic materials. Some systems for warm fog dissipation are expensive to install and use. However, a less expensive technique is that of using liquefied nitrogen (see the following entry), which has shown positive results in dissipating cold fog.

Page 6- An example of Italian involvement in weather modification concerns cold fog dispersal. Fog dispersal activities are meant to address the high incidence of fog in northern Italy during the colder seasons. The fog hinders both ground and aircraft operations, resulting in considerable economic loss. A technology using liquid nitrogen developed in the Russian Federation has been modified to suit local conditions and successfully implemented with international scientific advice. The technology uses ecologically safe liquefied nitrogen dispensers with output and dispersion patterns developed for optimum efficiency using numerical simulation. A 2-D numerical model was developed using weather parameters such as days with fog in different months, interannual variability, temperature, wind speed and visibility, as well as the characteristics of target areas in question, to conduct numerical experiments which permitted the formulation of the requirements for the airports of Parma, Milan and Verona. Despite the low occurrence of supercooled fog in the 1997-1998 season, positive results have been obtained during tests carried out at Parma, which favor the further implementation of the technology.

Page 7- Concerning ground traffic, the fog dispersal nitrogen technique has been used on the Venice-Trieste Motorway under various meteorological conditions at different sections of the motorway. During 1995-1998, experimental data were collected. Six stationary and one mobile liquefied nitrogen dispensers were used. Visibility increased considerably within 30 to 40 minutes after the use of liquid nitrogen.

The Smoke Dilemma: A Head-on Collision!
USDA Forest Service, 1998
http://www.srs.fs.usda.gov/pubs/rpc/1999-03/rpc_99mar_01.pdf.
Smoke emissions from prescribed burns can release large amounts of particles that scatter headlight beams from automobiles and create health hazards for people when inhaled. Visibility reductions caused by smoke or a combination of smoke and fog already have been implicated in multiple-car pileups, numerous physical injuries, heavy property damage and fatalities.

[WisDOT note: the following links present remedial technology:
* *New Technology Helps Fire Managers Anticipate Smoke Problems*
Science Daily- Sept. 19, 2003
http://www.sciencedaily.com/releases/2003/09/030918093632.htm.
(System Web site: http://www.blueskyrains.org/.)
Smoke from planned fires can seriously affect motorist visibility. BlueSkyRAINS is a technology that can provide accurate and timely information about planned fire-related smoke and visibility. Users can visit the centralized Web site to learn the potential accumulation of smoke from planned fires. The technology portrays the patterns of predicted smoke concentrations in relation to cities, hospitals, schools and other elements of interest.
* AlphaTRAC Smoke Management Tools
http://www.alphatrac.com/smoke/.
With increased wildland burning nationwide, better real-time estimates of smoke behavior have become essential to protecting visibility. The AlphaTRAC Smoke Management Center provides improved smoke behavior nowcasts and forecasts for wildland fire communities. The center also provides access to planning tools for smoke management.]

Emerging Technology

Caltech Engineers Design a Revolutionary Radar Chip
Caltech Media Relations- Feb. 9, 2004
http://pr.caltech.edu/media/Press_Releases/PR12490.html.
The High Speed Integrated Circuits group at the California Institute of Technology has used revolutionary design techniques to build the world's first radar on a chip -- specifically, the group has implemented a novel antenna array system on a single, silicon chip. The new technology helps pave the way for built-in radar systems for cars that will enable drivers to "see" the roadscape clearly on dark, foggy nights via an image screen in front of them.
Bradford Non-Lethal Weapons Research Project (BNLWRP)

Research Report 2- June 1998
http://www.bradford.ac.uk/acad/nlw/research_reports/researchreport2.php.
Scroll to 4.5 Laser:
4.5.1 Laser Dazzler – U.S. Defense Advanced Research Projects Agency and the National Institute of Justice (NIJ) have delivered a prototype Laser Dazzler to the U.S. Air Force and NIJ for evaluation. The advanced diode-pumped laser technology is being incorporated into a 250 milliwatt 532nm green-laser hand-held flashlight. The device includes a miniature laser and power supply and has output optics that temporarily expand the eye-safe laser into a blinding light. It can penetrate smoke and fog at more than twice the distance of white light. The dual-use technology is likely to be marketed separately to military and commercial markets.

Weather Control
From: Air Force 2025 Final Report (http://www.au.af.mil/au/2025/), Vol 3, Weather as a Force Multiplier
U.S. Air Force, Air University at Maxwell AFB, AL (August 1996)
http://www.geocities.com/Area51/Shadowlands/6583/project335.html.
Scroll to Fog:
There are some emerging technologies that may have important applications for fog dispersal. Heating is the most effective dispersal method for the most commonly occurring type of fog. Unfortunately, it has proved impractical for most situations and would be difficult at best for contingency operations. However, the development of directed radiant energy technologies, such as microwaves and lasers, could provide new possibilities.

Lab experiments have shown microwaves to be effective for the heat dissipation of fog. However, results also indicate that the energy levels required exceed the U.S. large power density exposure limit of 100 watt/m2 and would be very expensive. Field experiments with lasers have demonstrated the capability to dissipate warm fog at an airfield with zero visibility. Generating 1 watt/cm2, which is approximately the U.S. large power density exposure limit, the system raised visibility to one quarter of a mile in 20 seconds. Laser systems described in the Space Operations portion of this AF 2025 study could certainly provide this capability as one of their many possible uses.

With regard to seeding techniques, improvements in the materials and delivery methods are not only plausible but likely. Smart materials based on nanotechnology are currently being developed with gigaops computer capability at their core. They could adjust their size to optimal dimensions for a given fog seeding situation and even make adjustments throughout the process. They might also enhance their dispersal qualities by adjusting their buoyancy, by communicating with each other, and by steering themselves within the fog. They will be able to provide immediate and continuous effectiveness feedback by integrating with a larger sensor network and can also change their temperature and polarity to improve their seeding effects. Uninhabited aerospace vehicles could be used to deliver and distribute these smart materials.

<u>Enhanced Driver Visibility Safety System for the Petroleum Technology Alliance Canada</u>
(A proposal from Veridian Engineering Inc. to perform a problem assessment and present to the alliance findings and recommendations for a suitable solution.)
Dec. 13, 2002
http://www.ptac.org/has/dl/hasr0101b.pdf.
From Executive Summary:
The Canadian upstream oil and gas industry counts vehicle accidents as its single largest source of employee casualties and financial loss. Advanced and timely warning of dangerously large wildlife near or on the road, especially in limited visibility conditions such as in fog, snow, rain or darkness, has promise to significantly reduce the number of these accidents.
Scroll to Infrared Systems:
Infrared sensor technologies can be very effective in "seeing" through many of the most limited visibility conditions, including thick fog, heavy rain, snow, smoke and darkness. These particular technologies can be grouped into two general categories called "active" and "passive:"
* <u>Active infrared systems</u> employ a conventional visible light headlight or searchlight system, which is outfitted with a special filter that only allows infrared radiation to be projected ahead of the vehicle. The radiation is then reflected off of objects in a manner very similar to that of visible light. An image of the scene ahead is collected by a special sensor back in the vehicle and then recreated and displayed to the driver in one of several ways. It could be a liquid crystal diode (LCD) flat panel display, a cathode ray tube (CRT) monitor, or a head up display (HUD). Due to the nature of the wavelength of this active infrared radiation, some gains in the distance over which objects can be seen in limited visibility conditions can be obtained over that of the naked eye and conventional headlamp illumination. These active systems are relatively more expensive than enhanced visible light systems.

- <u>Passive infrared systems</u> actually "see" the temperature of objects in the infrared spectrum and display the variations of these temperatures as scenes. Two "windows" in the atmosphere allow this type of radiation to be propagated from objects to the passive infrared sensor, which is normally located on the front or top of a vehicle. These windows are in the three-to-five micron wavelength and in the seven-to-14 micron wavelength. Each of these has distinct advantages and disadvantages when it comes to performance and cost. The scene gathered by the passive infrared sensor is then displayed to the driver by one of the same methods described above. Generally speaking, the passive infrared systems are extremely effective in their ability to see long distances ahead through almost any limited visibility condition. Such systems employed on military platforms are capable of seeing and identifying targets of interest several miles away. The drawback of these systems has traditionally been their enormous cost, their great complexity (cryogenic cooling was typically required for the sensor to operate properly) and their lack of robust reliability. However, due to advances in technology and the proliferation of such systems, costs are coming down, complexity has been reduced and reliability has been improved.

Wisconsin DOT is investigating the use of Intelligent Transportation System technology to help mitigate the negative effects of weather-related, low visibility conditions on driver safety. A number of states have employed ITS technologies such as variable speed limit signs and dynamic message signs to display low visibility advisories or regulations to motorists and significantly reduce crash rates.[4]

[4]Low Visibility- Best Practices – FHWA Road Weather Management Program (2004) http://www.ops.fhwa.dot.gov/weather/weather_events/low_visibility.htm.